**Martian Crater Ejecta, Emplacement and Implications for Water in the Subsurface:** J. M. Boyce, Code SR, NASA Headquarters, Washington. DC 20546, and D. J. Roddy, U.S. Geological Survey (Emeritus), Flagstaff, AZ. 86001

The debate about the emplacement process for the fluidized ejecta surrounding many Martian craters has focused on effects of (1) the thin Martian atmosphere, and (2) volatile in the target materials (water or water ice). This problem has been approached using: morphological studies of impact craters on Mars and other bodies; experimental impact, explosion crater, theoretical and numerical studies. We suggested that combined results from these studies indicate that 1) subsurface volatiles (water) play a critical role in the origin of these craters and 2) the particular type of ejecta morphology was ultimately controlled by the phase of the water in the subsurface that existed during impact.

**Martian Crater Morphologic Studies**: Results from past ejecta morphologic studies appear to have contradictory elements. However, comparison of data produced by these studies suggests that there is agreement, though differences in approach and objectives of each study has often contributed to the appearance of conflicts. Collectively, these studies provide a generally consistent picture of Martian crater ejecta morphometry which is summarized below (see ref. 1-17):

1. There are several distinct morphologic types of ejecta blankets on Mars, of which some show evidence of flow during emplacement.
2. The distribution of some types of fluidized ejecta are correlated with latitude. In particular: a) pancake craters are limited to high latitudes and dominate the populations there, b) single-lobe craters occur in all latitudes but are less common in the northern mid-to high latitudes, c) multi-lobe craters occur only in mid- to low- latitudes, d) double-lobe craters are relatively more common in the northern mid- to high latitudes, e) ballistic ejecta craters occur at all latitudes, f) initiation diameter of each type of crater varies systematically with latitude.
3. Fluidized craters are not correlated with elevation.
4. Fluidized crater are not correlated with age of terrain.
5. There is a weak correlation with terrain type (only found for a few terrains).
6. There are size/morphologic feature correlations for: a) ejecta range (run-out distance) and crater diameter, b) ballistic ejecta craters dominate the population of craters below about 2-5 km diameter and above about 55-60 km, c) the average size and range of sizes is different for each type of fluidized crater, d) there is overlap in the range of sizes for each morphology type.
7. Fluidized crater onset occur simultaneously with other morphologic features (some of which are expected to result from volatiles in the target materials; such as diameter enlargement).

Some of the latitude-dependent relationships correlate with the expected depth-of-stability of ice (e.g., initiation diameter of pancake craters), while other latitude dependent relationships correlate with the expected subsurface freeze/thaw isotherm (e.g., initiation diameter of rampart craters). This is interpreted as suggesting that both water and ice may play a role in controlling the type of fluidized crater formed.

In addition, fluidized ejecta craters are absent on icy satellites indicates that simply having ice present is insufficient to cause ejecta fluidization (18). The absence of Mars-like craters on Venus (19) also suggests that simply the presence of an atmosphere is also insufficient to cause such Mars-style ejecta fluidization. This suggests that merely the presence of an atmosphere or ice in target materials alone are insufficient to produce fluidization like that on Mars.

**Experimental Impact and Explosion Crater Studies:** These studies have provided some insight into conditions that produce fluidized ejecta. Explosion crater experiments (high-explosion and nuclear) performed in wet targets have produced fluidized ejecta, but with no characteristic distal rampart (20-22). However, small-scale impact experiments in water saturated targets (23) have produced fluidized ejecta that more closely resembles Martian ejecta. Water saturated targets produce ejecta that travels in ballistic trajectories until it impacts the surface, where it flows outward as a slurry of water and entrained solid ejecta. Other small-scale impact experiments also produced ejecta flow but used dry fine-grained target materials under varying atmospheric conditions (24, 25). These experiments show systematic change in the ejecta curtain that includes bulging at the base and pinching above. This behavior has been suggested to reflect the combined effects of 1) deceleration of smaller size ejecta and 2) entrainment of these ejecta within the atmospheric vortices created as the outward moving wall of ejecta displaces the atmosphere (25). In these experiments, the velocity of the ejecta and grain-size are key parameters that control fluidization. These are also parameters that are significantly effected by the presence of water in the target materials.

Significant amounts of water in the target materials are known to effect the cratering process as well as ejecta emplacement process (20, 21 22, 26, 27). The presence of water commonly reduces the strength of materials and for an equivalent energy coupling produces larger craters in wet media than in dry media. The comparatively low-vaporization energy of water result in generation of significant gas phase which dramatically increase pressure in the cavity and the cratering efficiency. As a consequence, larger diameter craters and higher velocity ejecta are produced for a particular energy. In addition, to these effects, water in target materials is also expected to result in the production of fine-grain materials in the ejecta. For example, Wohletz and Sheridan (28) using explosion experiments found that fine grain particles are produced in explosion events when significant amounts of water is present. In addition to the production of fine-grain materials, liquid water in ejecta would be dispersed and atomized into fine-grain particles that could significantly contribute to the process of ejecta flow. Therefore, water in the target materials would significantly enhance flow in ejecta, especially in the presence of an atmosphere. Ice in the target materials is expected to produce less dramatic effects because most ejecta it may not be shocked to a high enough pressure to melt of vaporize water ice (26, 29).

Conclusions: There are systematic changes in Martian crater morphology. These changes are most simply (but not uniquely) related to the distribution of subsurface water and ice on Mars. Though both suggested dynamical fluidized ejecta emplacement mechanisms could provide the observed relationships; atmospheric effects combined with the effects of significant water in the subsurface provide a model that best fits the observations. However, other factors may also play a more subtle role in emplacement of this type of ejecta (e.g., potential of unique relationship of the gravity of Mars and the rheology parameters).

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